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TECHNICAL REPORT
EP-160

EFFECT OF REDUCED RATION AND METHOD OF LOAD CARRYING ON PHYSICAL FITNESS AND ENERGY EXPENDITURE OF SMALL GROUPS OF MEN OPERATING ON THE GREENLAND ICECAP

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

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FOREWORD

Several features of the Greenland icecap provided an unusual laboratory for the study of human performance. It contained a uniform surface so necessary for a reproducible exercise regimen from day to day. Also, it gave very little opportunity to supplement the ration from unauthorized sources.

An additional reason for selecting this site was its unusual environment due to the absence of variation in terrain and activity. Man does not frequently visit this environment and has been rarely studied there.

Many studies on the effect of inadequate caloric intake on human performance have been done in the laboratory, but the laboratory environment may lack some of the factors which influence man's performance in a field situation. Moreover, the efficiency of various methods of human load-carrying had not been measured on this terrain.

Finally, it should be noted that measurements were made at the same time on food consumption and preferences and on the socio-psychological responses of man to these unusual living conditions.

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ABSTRACT

Early in the summer of 1960 a group of 19 young soldiers were transported from Fort Lee, Virginia, to the Greenland icecap where they were studied during 2 treks of 10 days each over the icecap. A period of training and acclimatization preceded the studies and some measurements were made both before and after each trek. Finally, some measurements were also made at sea level after return to Natick, Mass.

The subjects hiked 8 miles each day, divided into 2 major groups: one living on a full ration, and the other on a ration reduced by about 40% of the voluntary caloric intake. Both groups were further subdivided according to either of two methods of load carrying: (1) on the back and sled, (2) entirely on the sled. The method was alternated for each man during the second half of the 10-day period; also the alternate ration regimen was used during the second period. The following measurements were made:

(1) Physical fitness was measured by performance on the Harvard step test before and after each experimental period. After return to sea level, performance on this test was also compared with performance on the treadmill. In addition, the subjects ranked each other by their subjective estimate of fitness.

(2) A mild step test called the Altitude step test was used to compare metabolic and respiratory requirements at the altitude of the icecap (7,000 feet) with that of sea level (actually 165 feet).

(3) Energy metabolism was measured for extended periods during the daily trek by a meter located in a face mask; this used the principle that the energy metabolism is directly related to the respiratory volume. However, after return to Natick, it was necessary to measure this relationship for each man because of individual variation.

(4) Body weights were measured frequently.

It was found that a reduction of caloric intake of about 40% below the voluntary intake and a resultant 4.5% decrease of body weight during 10 days of hard work did not noticeably affect the performance on the Harvard step test in spite of the high level of exercise and also low motivation. There was, however, subjective evidence of deterioration in the form of a greater sense of fatigue, a lack of enthusiasm, and an increased irritability. Other tests for fitness, the treadmill test and subjective evaluation, did not correlate closely with the Harvard step test.

Even though the energy cost of work on the icecap decreased from the beginning to the end of the 10-day experimental period, the reduction was not greater on the reduced ration than on the full ration on a body-weight basis. A load was pulled more easily on sled than carried partly on the sled and partly on the back on the type of snow surface present in this study.

At around 7,000 feet there was an increase of 8% of the respiratory volume above that at sea level after adjustment to standard temperature and pressure. The volume of inspired air during performance of the mild step test remained higher for at least 12 days after return to sea level, but dropped to the lower level by 19 days at sea level. There is some evidence of an inverse relationship between the volume of inspired air and the scores on the Harvard step test.

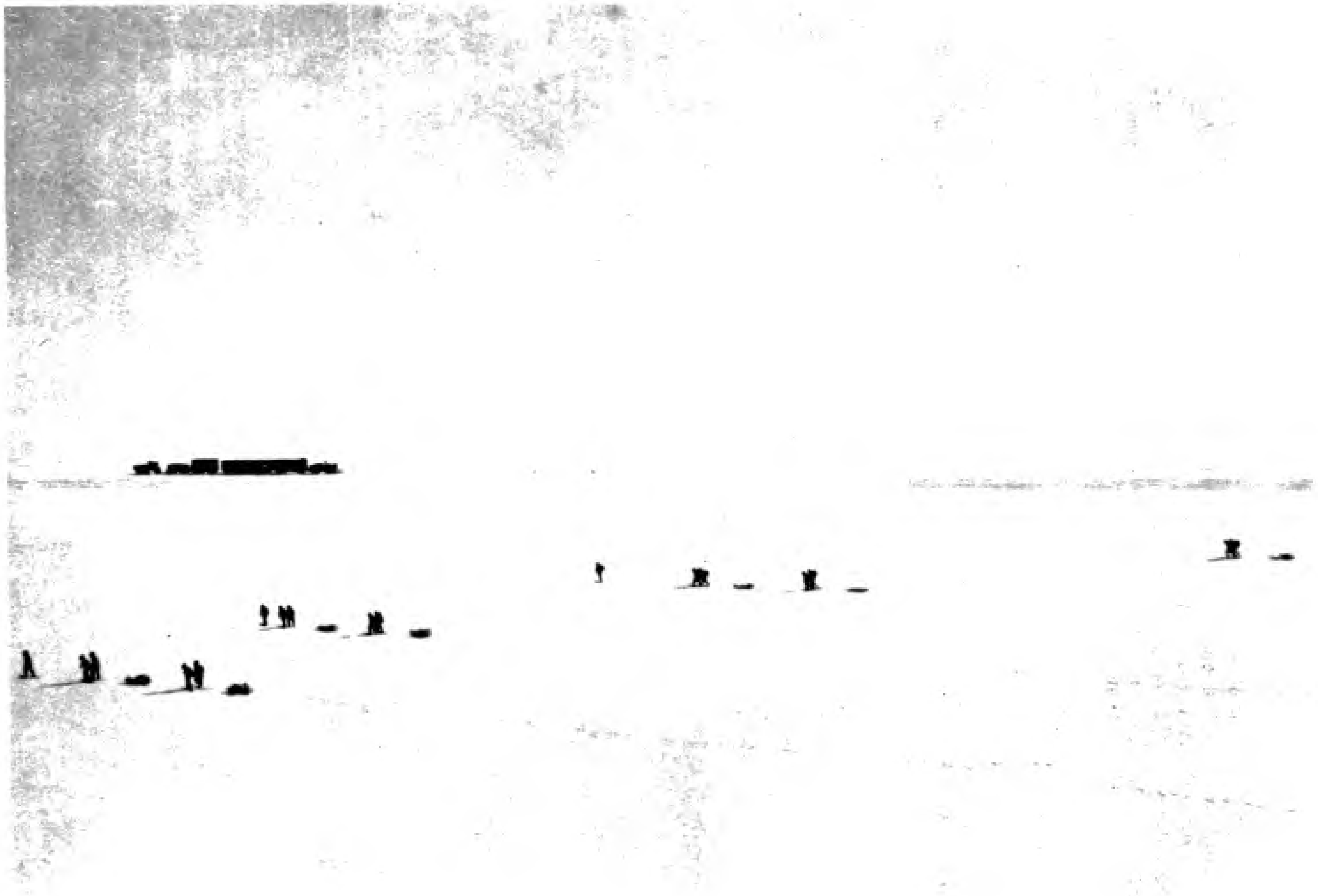

Figure 1 Teams of soldiers trek across the endless icecap. Only the tractor train containing a laboratory and supplies breaks the monotony of the trackless waste.

EFFECT OF REDUCED RATION AND METHOD OF LOAD CARRYING ON PHYSICAL FITNESS AND ENERGY EXPENDITURE OF SMALL GROUPS OF MEN OPERATING ON THE GREENLAND ICECAP

1. Introduction

Armies in action and men competing in sports do not look favorably upon the delays and hindrances involved in physiological testing. Yet field testing is necessary in order to get a more accurate picture of the total effect of all the stresses operating on the individual. In the field, physiological and psychological factors interact to produce results sometimes unpredictable from laboratory tests of single variables.

Since military groups must be prepared to operate and survive under any extreme situation, it was considered necessary to know more about the problems of living on the Greenland icecap and the capabilities of small groups to move on foot. Moreover, this environment provides good conditions for studying the effects on the soldier's performance of a reduced ration and of two methods of load carrying. The basic measurable responses selected for study were:

a. Physical fitness (as measured by a test of endurance and by subjective evaluation).

b. Energy required to perform work.

c. Total body water. Samples of urine containing deuterium oxide were collected in the field; but difficulty was experienced in modifying the falling-drop method of analysis for use on urine samples, so the results are unknown. No further detail will be included in this report.

d. Body weight.

Other measurements were made at the same time by a group from the Quartermaster Food and Container Institute of Chicago (since moved to Natick, Massachusetts) who have published their results separately.

These measurements include food consumption and preferences* and socio-psychological attitudes toward other members of the test group and toward the investigator.**

a. Selecting and Training Test Subjects

Twenty-eight soldiers from Fort Lee, Virginia, were assigned as test subjects; of these, nine were judged to be unsuitable for carrying out the experimental requirements. The age, height and weight of the remaining 19 men who served as test subjects are given in Table IX in the appendix. Even though the soldiers were taken from a volunteer test subject pool, they generally were not eager about this assignment because of the previous experience of some of them in Greenland. As a result, the motivation and morale of the men was not as high as would have been desirable.

Physical conditioning and training in camp skills were carried out daily at Fort Lee for 2 weeks before the men left for Greenland. The conditioning involved mainly hiking (with or without a heavy rucksack) from 2 to 6 miles per day except for one 15-mile hike. The subjects were flown from Virginia to Thule, Greenland, where they arrived on July 3, 1960. Two days later they left on a 6-day "swing" by tractor train for Camp Fistclench, 220 miles inland on the icecap. This camp, completely below the surface of the ice, served as the headquarters for the research group when they were not out on a 10-day trek across the icecap. In a limited way, the facilities at Camp Fistclench were similar to those of most Army camps.

From July 16th to 20th, training was continued on the icecap and was terminated by a snow storm and "whiteout" which lasted from the 21st to 25th of July. During the 5 days of training, the subjects wearing snowshoes walked 5 to 10 miles each day on the icecap. They used full equipment and practiced camping techniques and testing methods. This included the use of the respiratory masks and the performance of the Harvard step test in an abbreviated form. Extensive briefings were given on the objectives and methods of the testing procedures.

b. The Greenland Environment

The Greenland icecap is a massive body of ice and snow that covers about 85 percent of the entire area of Greenland, leaving land exposed only along the coastline. The depth of ice increases with increasing distances inland from the coast up to a height of 10,000 feet. Where the test team operated, the altitude was from 6,000 to 7,000 feet; this depth is believed to consist entirely of ice. No land is visible under foot

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* Food consumption and preferences under conditions of restricted and non-restricted feeding. AMXFC Rept. No. 40-62, Dec. 62.

** Hunger in Groups: An Arctic Experiment. QMFCIAF Rept. No. 34-62, Aug. 62.

or on the horizon, and the surface of the ice is very level in every direction; no vegetation exists and no animal life will be seen except an occasional stray bird. The surface is covered without interruption by white snow. (See Fig. 2.) No landmarks are visible except, at various intervals, flags marking the caterpillar trail from the coast to the camp. This setting is continuously illuminated by sunlight for 24 hours a day during July and most of August, except for an occasional "whiteout" when the distinction between the icecap and the sky becomes blurred. This is a barren and desolate environment which is very monotonous for anyone accustomed to the great variety of terrain and vegetation usually found in a temperate climate.

The surface of the snow did not usually support a man wearing shoes or boots. The boot would penetrate into the snow from a few inches up to 2 feet in depth. Therefore, snowshoes were worn regularly, they supported the foot within 2 inches of the surface and made walking relatively easy. (See Fig. 2.) The snow surface was ideal for the sleds and offered relatively little resistance.

The meteorological conditions of this area during the working hours are summarized in Table X in the appendix. The average ambient temperature during any morning or afternoon work session ranged from 11° to 28°F, averaging close to 20°F for the two sessions. Occasionally, temperatures would drop below zero in the early morning hours. The average wind velocity for any morning or afternoon session ranged from 0.2 to 14.6 mph, with an overall average of 8.1 mph during the working hours. There were occasional spells of higher wind velocities.

c. <u>Experimental Design</u>

Nineteen men were divided into 4 groups (Groups A, B, C, D, of 4, 5, 5, 5 men each) who worked as isolated units sharing with group members in the daily work as well as the tent activity at night.

Two groups were on full rations (4800 Cal) and two on reduced rations (2400 Cal) during the two 10-day experimental periods. The type ration for both was the Meal, Combat, Individual. The Garrison ration was eaten at all other times and was well prepared and plentiful.

The subjects were further subdivided so that both groups on each ration used a different load-carrying system for the first half of the experimental period and then changed to the other system for the second half (for the schedule, see Table I). In the second period the rations also were reversed. For the sake of the sociological study performed by the Army Quartermaster Food and Container Institute, 3 team members

Figure 2 A complete team of five accompanied by an investigator. The load is carried on back and sled.

TABLE I

INDIVIDUAL RATION AND LOAD CARRYING SCHEDULE

Period I					Period II				
			Load Carrying					Load Carrying	
Subject	Group	Ration	1st Half	2nd Half	Subject	Group	Ration	1st Half	2nd Half
1					1	A		S	S&B
2	A	F	S	S&B	2	B	R	S&B	S
3					3	B		S&B	S
4					4	B		S&B	S
5					5	B		S&B	S
6	B	F	S&B	S	6	B	R	S&B	S
7					7	A		S	S&B
8					8	A		S	S&B
9					9	A		S	S&B
10					10	C		S	S&B
11					11	C		S	S&B
12	C	R	S	S&B	12	D	F	S&B	S
13					13	D		S&B	S
14					14	D		S&B	S
15					15	D		S&B	S
16					16	D		S&B	S
17	D	R	S&B	S	17	C	F	S	S&B
18					18	C		S	S&B
19					19	C		S	S&B

Ration: F: full ration R: reduced ration
Load: S: Load carried completely on sled
S&B: Load divided between sled and subject's back

were exchanged between groups A-and-B, and C-and-D*. The loads were carried either entirely on 2 sleds (S) or divided between packs on the back and sleds (S&B). Each sled was pulled by two men while the fifth man (or in Group A, the fourth) preceded the others to break trail. Positions were rotated several times each day. When the total load was on the sled, the average weight of each sled was 97 kg; when it was on back and sled, each sled averaged 56.6 kg and each pack 14.7 kg. Individual values for load carried or hauled can be seen in Table XI in the appendix.

The two 10-day experimental periods were separated by 7 days of rest and testing at Camp Fistclench. Harvard step tests and Altitude step tests (to be described later) were made during the experimental "on trail" period. The schedule of tests is shown in Table II.

TABLE II

SCHEDULE OF TESTS FOR SECOND PERIOD

	PRE-TRAIL (2 Days)		ON-TRAIL (10 Days)								POST-TRAIL (2 Days)	
	Day 1 HST ALT.	2 HST ALT.	1	2	3	4	6	7	8	9	1 ALT HST	2 ALT HST
			Metabolism During Walking ($\dot{V}_{O_2}$)									
A.M.	A,B (9* C,D Men)		A,D	B,C	A,D	B,C	B,C	A,D	B,C	A,D		(9* A,B Men) C,D
P.M.		A,B (9* C,D Men)	B,C	A,D	B,C	A,D	A,D	B,C	A,D	B,C	(9* A,B Men) C,D	

HST - Harvard Step Test
ALT - Altitude Step Test
* For the Altitude step test, 9 men were drawn from the 4 groups.
Note: Pre-and post-trail test schedule was the same for the first period.

On the trail, only one physiological test was made: metabolism ($\dot{V}_{O_2}$) during hiking. Each man was measured once a day for 2 hours, either in the morning or afternoon. The 2 testing hours were divided into alternate periods of 20 minutes of walking and about 5 minutes of rest (see Fig. 3). Readings of the air-flow meter (explained later) were made at the beginning and end of each walking period.

* Group A-and-B may be considered a "team", when compared with Group E-and-D, as the second "team".

Figure 3 Typical scene during the 5-minute rest period in the daily trek. Men prefer to leave the heavy pack on the back rather than make the effort of taking it off and putting it back on.

The subjects were instructed to walk at the same speed; thus the slowest team set the pace, except occasionally when these instructions were not perfectly obeyed.

Life on the trail was characterized by the exigency of travel on foot and nightly camping on the snow surface, plus the interruptions of frequent test procedures. Both day and night, the four groups of 4 or 5 men each were separated by a distance of a few hundred feet and were essentially independent of each other and of the tractor train which moved along at a distance from the men. This train served as a laboratory for servicing equipment, as living and working quarters for investigators, and as an infirmary for ill or disabled men.

The daily 8 miles of walking on snowshoes was evenly divided between morning and afternoon. The halting of the train in the distance at about 11:15 A.M. and 2:30 P.M. signalled the halfway and terminal points, respectively, for each day. At the halfway point, a trail break of about 45 minutes was taken when the men ate a light noon meal of items from the measured ration that required no warming. Windbreaks were hastily constructed from cut blocks of snow. At the terminal point for each day tents were erected, equipment unpacked, latrines dug in the snow, and plans made for a long restful evening. Tents were generally erected by 3:30 P.M. For a brief schedule of daily activity see Table III.

TABLE III

SCHEDULE OF DAILY ACTIVITIES DURING EXPERIMENTAL PERIODS ON THE TRAIL

0630 Hours	Reveille
0630 to 0800	Morning toilet, hot breakfast
0800 to 0845	Break camp, (strike tent, pack equipment on sled, fill in latrine, etc.)
0845 to 1115	<u>Morning march</u>, 4 miles, $\mathring{V}_{O_2}$ measurements
1115 to 1200	Rest, cold lunch - psychological measurements
1200 to 1430	<u>Afternoon march</u>, 4 miles, $\mathring{V}_{O_2}$ measurements
1430 to 1500	Make camp (unload sleds, pitch tent, erect stove, dig latrine, etc.)
1500 to 1630	Rest in tents
1630 to 1800	Prepare and eat hot evening meal in tents
1800 to 2100	Interviews and questionnaires with psychologists in tent
2100 Hours	Sleep

Adequate protection from cold exposure was provided by the standard Army cold-weather clothing. During the tests, food was heated in pressure cookers on gasoline-burning Yukon stoves. These stoves were allowed to heat the tent until the time of retiring for the night. For sleeping, two down-filled sleeping bags on an air mattress were placed directly on the snow surface. Rations and gasoline were supplied each day from the tractor train.

2. Description of test methods

a. Physical fitness tests

Although physical fitness has several aspects, endurance is the one being measured here and may be defined for our purposes as "the ability to do sustained hard exercise of the walking or running type."

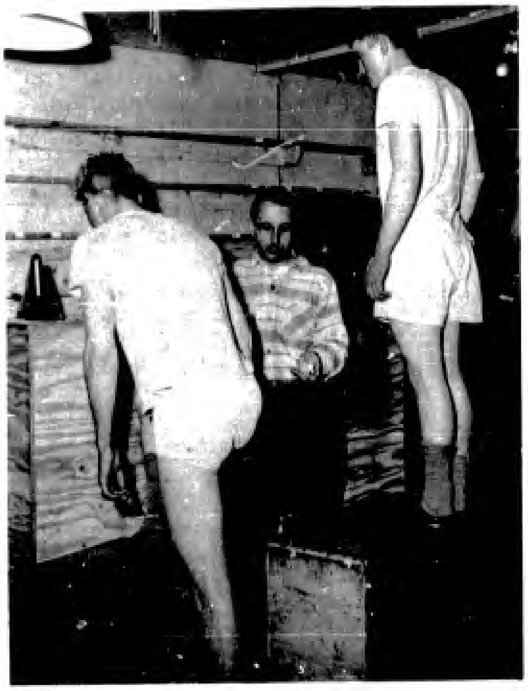

Figure 4 Performing the Harvard step test in a storeroom in a tunnel built into the icecap.

Harvard step test It is generally agreed that there is no single fully adequate measure of physical fitness. However, the Harvard step test (1) hereafter referred to as HST, appears to be more consistent with performance than most other tests and is probably the one most commonly used. (See Figure 4.) It was selected for use in the present study because of the need for a simple method for field use. The principle assumes that the rate of recovery of the heart rate to resting levels after a period of strenuous exercise is directly related to the fitness of the body or the ability to perform sustained hard exercise.

Treadmill test However, since it had been suggested by some workers, whose work is reviewed by Astrand (2), that a test based on the heart rate during, rather than after, exercise would be a better measure of ability to perform hard work, a treadmill test was designed to be used upon return to near sea level (165 ft.) to compare the levels of fitness among men. This test provided increasing levels of work until a critical level of heart rate was reached. It used a constant running speed of 7 mph at a starting vertical grade of zero; this was increased by 0.5 percent at the end of each minute until the end of the test. Every 2 minutes the subject stepped off the treadmill for 15 seconds. At this time, the pulse rate was counted by palpation of the radial artery for 10 seconds and then the subject returned immediately to the treadmill. When the pulse rate reached 180 or more beats per minute, the subject returned to the treadmill for another minute. If the pulse rate remained at this level or was higher at the end of the second minute, the test was terminated and the length of time of running was used as the fitness index. This method of pulse counting is easier to use than a running pulse and gives identical values. The conditions of this treadmill test were dictated mostly by the grade limitations of the treadmill. A running pace was necessary because the highest grade attainable was only 12.5 percent which was not enough to bring the heart rate to the cut-off point at a walking pace.

Respiratory volumes as a test of fitness Respiratory volumes for any task involving high levels of oxygen consumption are generally found to be lower when the individual is at a high level of physical fitness than when he is at a low level.

Respiratory volumes were not measured here for the purpose of studying fitness but they were obtained here in the course of other measurements.

Subjective estimates of teammates' fitness It was felt that subjective estimates of the endurance and of the ability to survive on the icecap made by teammates and investigators would have some value in determining the fitness of the subject since they were so intimately involved with each other in every aspect of work and camp life.

b. Energy metabolism: advantages and theory of mask-meter methods

Methods for measuring energy metabolism during work in the field usually involve measurements of the volume and concentration of the gases of the expired air. These methods have two major disadvantages which would have been serious problems in this field study. First, the air samples can be collected for only short periods of time because of the large volumes involved. Thus, in order to determine energy expenditure for long periods of activity, the assumption must be made that the level of energy expenditure remains constant. Secondly, the methods are tedious and time-consuming and involve the use of special equipment and electricity. Therefore, another method was needed. The one chosen required only the use of a face mask containing a small air-flow meter. The principle involved was observed by Boothby in 1915 (3) and used by Durnin *et al.* (4) and Ford *et al.* (5) and states that oxygen consumption (V_{O_2}) is rectilinearly related to respiratory volume under most conditions. Ford studied this relationship and expressed it as

$$Y = 0.52 + 0.173X$$

where Y = rate of energy expenditure in calories per minute, and X = rate of respiration in liters per minute. Another investigator, Sartorelli (6), reported a slightly different formula for young adults:

$$Y = 0.26 + 0.204X$$

It was reported by Durnin that there is considerable individual variation from these mean formulas due to physiological variability. Therefore, to accurately determine $\mathring{V}_{O_2}$ or caloric expenditure from the inspiratory volume ($\mathring{V}_I$) it is necessary to establish the relationship of $\mathring{V}_I$ to $\mathring{V}_{O_2}$, known as the ventilatory equivalent, for each individual. This was done in the present study 2 weeks after the field phase was completed and the subjects had returned to the Natick laboratory. Two slopes on the treadmill were selected to produce amounts of exercise comparable to the highest and lowest amounts of exercise required during the daily trek on the icecap. The lower level of walking was 3 mph at zero slope, and the high was 3.5 mph at 11.4 percent slope. The values are plotted in Fig. 11, appendix.

c. Operation of mask and meter

The meters of the masks were individually calibrated in order that meter readings could be translated to known volumes. This was done by placing the meter in the center of a system of instruments connected by air hose with a pump on one end which drew air through the meter from a spirometer on the other end. The flow was made to pulsate, to imitate human breathing. All spirometer volumes were adjusted to STPD (standard temperature and pressure, dry). The calibration formula for every mask is listed in Table XII, appendix. By making trials at various temperatures, it was found that the air temperature did not affect the calibration factor. The mask is a standard gas mask made to have a broad area of contact with the skin along the edges of the mask. (See Fig. 5.)

The meter consists of a small turbine in a plastic cylinder through which holes were drilled tangentially. Upon inspiration air drawn through these channels from outside strikes the turbine blades perpendicularly, causing them to rotate. The turbine was connected by a shaft to a series of clock gears which moved a numbers dial. From this dial (see Fig. 6) readings could be made at the beginning and end of a period of measurement. A windshield (Fig. 7) was required to prevent the wind blowing from the side or front, from turning the turbine. The expired air was expelled through a valve placed low in the mask; this valve also allowed escape of condensed water vapor and saliva. A more detailed description of this method is being prepared by Potsch et al. (7). Since this was the first field trial, various problems were found in the use of this system. Occasionally ice formed around the turbine. This occurred only when the mask was removed after a period of heavy exercise at air temperatures around 0°F or below, and a small amount of water, which had collected in

Figure 5 Meter and mask for measuring of inspired air

Figure 6 Components of the air meter. A turbine is connected to mechanical gears which turn the dial

Figure 7 Air meter showing windshield

the mask, had leaked forward through the valve. Fogging of the eye glasses was another problem. Condensation of moisture from the saturated expired air was aggravated by the low environmental temperatures. A mask especially designed for this purpose should not cover the eyes. After 1 to 2 hours of use the mask sometimes caused discomfort and aching of the face; this was relieved only by removal of the mask for a few minutes.

This meter could not be used for low levels of ventilation. First of all, the arrangement of air holes and turbine was designed for higher levels of air flow as found when subjects move about; air will leak past the turbine at low respiratory volumes. In addition, the system cannot be used at low levels of respiration because the ratio of $\mathring{V}_{O_2}$ and V_I increases. The dead air space may be a critical factor. This relationship changes at high ventilation volumes. Durnin *et al*. (4) place the lower and upper limits at 15 and 45 l/min, respectively.

d. Calculating $\mathring{V}_{O_2}$ from meter readings and altitude step test

The turbine of the mask meter responds to the mass of the air and not to its volume (7). Therefore, altitude and temperature have no appreciable physical effect on the meter readings, and the volume of air obtained by using the calibration formula is at standard temperature and pressure (STPD), even though the total volume of air passing through may be altered considerably. However, it was not certain whether the mass of air required by the body at 7,000 feet would be the same as at sea level. If it were different, the curves that relate $\mathring{V}_I$ to V_{O_2} determined near sea level (Fig. 11, appendix) would not be accurate at 7,000 feet.

In order to resolve the question and possibly derive an adjustment factor, a standard exercise was performed at both sea level and 7,000 feet on the ice cap. This exercise (hereafter called "altitude step test") involved stepping on and off a stool 15-1/2 inches high at the rate of 20 complete steps per minute for 10 minutes. The assumption was made here that the V_{O_2} and caloric requirement for a standard workload is identical at both altitudes; this is supported by the work of Rahn and Otis (8), Schilling *et al*. (9) and Pugh (10). To derive an adjustment or "altitude factor", the percent change is subtracted from 100 and divided by 100. This altitude factor was determined for 9 men only.

The final formula for the determination of $\mathring{V}_{O_2}$ at 7,000 feet from a respiratory mass flow meter is:

Mask meter reading (mass of air in meter units)	X	Mask calibration formula (Table XII appendix)	X	Altitude factor	=	Respiratory volume required to do equivalent work at sea level (l/min)

This respiratory volume can then be found on the $\mathring{V}_I$ vs $\mathring{V}_{O_2}$ chart (Fig. 11

appendix) previously determined for each subject and the equivalent $\dot{V}_{O_2}$ can be read directly from this chart.

Calculations can be made for separate comparisons of the volumes of air breathed at the two altitudes.

3. Results

a. Effect of rations on body weight

There was a reduction of body weight for men on both the full and reduced ration (Fig. 8). This suggests that caloric intake was inadequate. On the full ration, which allowed up to 4800 calories per man for each 24-hour period, only 3614 calories were eaten by Groups A-and-B and 4150 calories by Groups C-and-D. For individual food consumption, see Table XIII, appendix.

Full ration Body weights fell an average of 1.6 kg in Period I and 1.8 kg in the second period on the full ration; they decreased most rapidly at the beginning of the period and levelled off in the latter part (Fig. 8). It might be reasonable to expect that upon change from a luxus diet of garrison rations to a field ration which almost invariably has a poorer taste quality, there would be an initial decrease in food intake. This frequently happens after initiation of new dietary regimens. The items most commonly discarded were tuna and noodles, turkey loaf, beef steak, ham and potatoes and coffee. Another cause of weight loss could be a decrease in total body water. This is not uncommon in field situations in the cold where drinking water often freezes and where overheating of the body frequently occurs during exercise. Unfortunately, total body water measurements will not be available, as explained earlier. The difference in voluntary food consumption between the two groups (A-and-B and C-and-D) may be related to the difference of 2.8 kg in body weight between the two groups at the beginning of each period.

Reduced ration On the reduced ration where 2400 calories per day were available, an average of 2328 calories in the first period and 2350 calories in the second were consumed. The difference was due to the cream and sugar not used in the coffee of some subjects. This represented a reduction of 43.9 percent and 34.8 percent below the voluntary food intake for Group C-and-D and for Group A-and-B, respectively. As a result of the reduced rations, body weights decreased 2.7 kg for one "team", and 3.8 kg for the other, which is a mean 4.5 percent decrease. It should be noted that although the percent reduction of caloric intake (43.9%) was larger for Group C-and-D, the mean body weight dropped less (3.7 kg) for these groups than for Group A-and-B.

b. Effect of reduced rations on endurance and performance

Physical endurance of those on both rations improved during the 10-day experimental periods (see Table IV; for individual values see Table XIV, appendix).

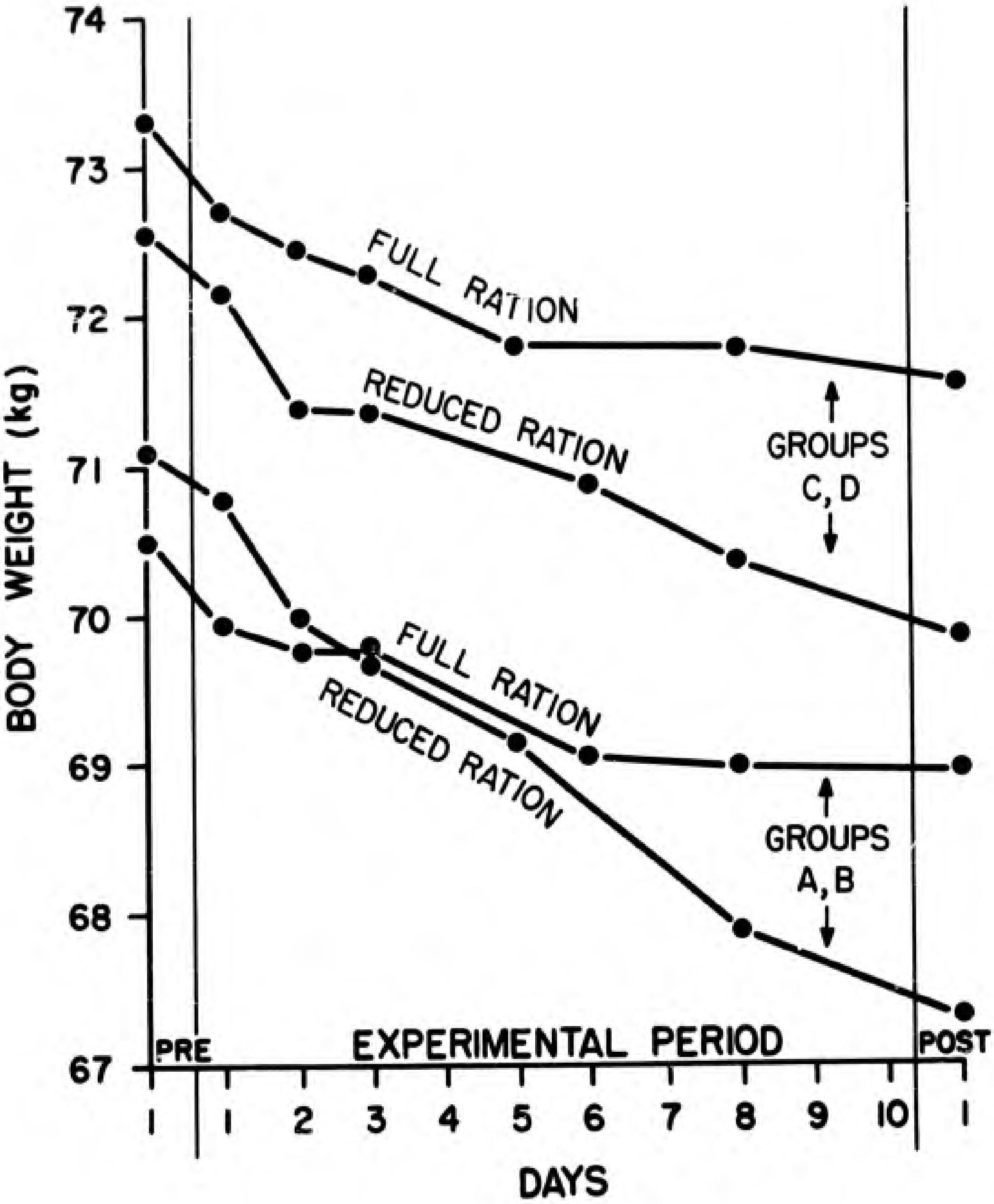

Figure 8 Comparison of body weights by type of ration during the treks on the icecap.

TABLE IV

MEAN HARVARD STEP TEST SCORES AND BODY WEIGHTS BEFORE AND AFTER EACH 10-DAY EXPERIMENTAL PERIOD

RATION	Harvard Step Test Score Before	After	%Δ	Body Weight (kg) Before	After	%Δ
			1st Period			
FULL	81	94	+16	70.50	68.95	-2.2
REDUCED	78	92	+17.9	72.53	69.84	-3.7
			2nd Period			
FULL	84	89	+6	73.3	71.53	-2.4
REDUCED	86	93	+8	71.09	67.30	-5.3

The reduced ration apparently had no bad effect on endurance. This can be seen by a comparison of the Harvard step test (HST) scores. In the first experimental period, the scores increased 16 and 17.9 percent on the full and reduced ration, respectively, while in the second experimental period, the increase was 6 and 8 percent. Thus, within each period, regardless of ration, the values were very similar.

Since, by the end of the experimental period, body weight had decreased more on the reduced ration than on the full ration, the total energy expended and the total work performed on the HST were also less for those on the reduced ration. As a result of this decreased demand on the body when performing the test, it might be expected that the HST score would be improved on the reduced ration. Since this is not apparent from the net results, it is possible that the reduced ration had some deteriorating effect on endurance which was masked by the beneficial effect of the weight loss. Even though the HST indicated that the ability to perform strenuous exercise had not changed, subjective observations of performance during the period suggest that the subjects tired more rapidly, felt weaker, were more irritable and had less enthusiasm than when on the full ration.

Comparison of two periods From Table IV we can also see that there was deterioration of the HST score during the week of rest between the two periods (94 to 84 for those previously on full ration; 92 to 86 for those previously on a reduced ration). However, the scores remained above the values at the beginning of the first period in spite of the greater body

TABLE IV

MEAN HARVARD STEP TEST SCORES AND BODY WEIGHTS BEFORE AND AFTER EACH 10-DAY EXPERIMENTAL PERIOD

RATION	Harvard Step Test Score Before	After	%Δ	Body Weight (kg) Before	After	%Δ
			1st Period			
FULL	81	94	+16	70.50	68.95	-2.2
REDUCED	78	92	+17.9	72.53	69.84	-3.7
			2nd Period			
FULL	84	89	+6	73.3	71.53	-2.4
REDUCED	86	93	+8	71.09	67.30	-5.3

The reduced ration apparently had no bad effect on endurance. This can be seen by a comparison of the Harvard step test (HST) scores. In the first experimental period, the scores increased 16 and 17.9 percent on the full and reduced ration, respectively, while in the second experimental period, the increase was 6 and 8 percent. Thus, within each period, regardless of ration, the values were very similar.

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Comparison of two periods From Table IV we can also see that there was deterioration of the HST score during the week of rest between the two periods (94 to 84 for those previously on full ration; 92 to 86 for those previously on a reduced ration). However, the scores remained above the values at the beginning of the first period in spite of the greater body weights (average of 0.7 kg) at the beginning of the second period.

HST scores during the second period did not increase as much as during the first period, while body weights decreased more than during the first period in spite of greater caloric intake. One can only speculate what this means. Certainly if trail skills were improving so that less work was being done and as a result less training being effected, then less energy would be expended and body weights would remain higher rather than lower than in the previous period. Another possible reason for the smaller increase in HST during the second period than during the first period, is that there is deterioration in the efficiency of physiological mechanisms due to inadequate recovery from the previous period.

Individual variations There was individual variation in the response to exercise. Two men (man 2 and 16) showed very little change in the HST score during the two periods, while two (man 10 and 17) showed lower scores during the second period. These last two men were the same who also appeared to do the least work on the trail; this observation was also confirmed by their level of V_{O_2}/kg of body weight.

c. Comparison of Harvard step test (HST) with treadmill scores and both with estimates of performance.

Because of the criticism sometimes directed at the HST, the subjects were tested on a treadmill test when they returned to Natick. A comparison of scores of the treadmill test with those of the HST at the end of the experimental period for all individuals is given in Table V.

TABLE V

FITNESS TESTS AND SUBJECTIVE EVALUATIONS COMPARED BY SPEARMAN'S COEFFICIENT OF CORRELATION

Relationship	Teams A-&-B	Teams C-&-D
Harvard step test vs treadmill test	.185	.575
Harvard step test vs investigator evaluation of endurance	.570	.817*
Harvard step test vs subject evaluation of endurance	-.367	.250
Treadmill test vs investigator evaluation of endurance	.348	.267
Treadmill test vs subject evaluation of endurance	.332	.142
Investigator evaluation of endurance vs subject evaluation of endurance	.264	.550
Investigator evaluation of endurance vs subject evaluation of ability to survive on ice	.533	.840*
Subject evaluation of ability to survive on icecap vs subject evaluation of endurance	.173	.738
Subject evaluation of ability to survive on icecap vs Harvard step test	.461	.388
Subject evaluation of ability to survive on icecap vs treadmill test	.542	.138

* Relationships showing the highest correlation

These tests are not highly correlated. The question that naturally follows is, "Which of the two tests is a better measure of the relative physical fitness?" Since there is no absolute test of ability to perform work, short of working to exhaustion, this question is hard to answer. However, an attempt was made by comparing each of these physical-fitness tests with subjective estimates of ability to perform (endurance) on the icecap. The subjects ranked their team-members' strength and endurance as judged by their performance on the trail and signs of fatigue at the end of the day. The investigators made similar rankings (Table XV, appendix). The rankings were made in two "teams" because members of Groups A-and-B had not worked with members of Groups C-and-D in either experimental period.

In Table V it can be seen from Spearman's coefficient of correlation that the rankings by the test subjects were not similar to the rankings by the investigator. Moreover, neither test of physical fitness was closely correlated with either subjective ranking except in one case: HST versus investigator's ranking for team C-and-D. It should be noted that even this higher correlation may have been conditioned by the investigator's previous knowledge of some of the high and low scores on the HST. Therefore, little can be said about the relative merits of the two tests of physical fitness from the subjective evaluation.

In addition, the subjects ranked each other on their ability to survive by themselves on the icecap. Here, also, a low correlation was found with both the rankings of performance on the HST and treadmill test and also with their rankings of each other of actual physical endurance. This suggests that the subjects consider factors other than physical endurance important for their performance

d. Metabolism during work - effect of ration and load-carrying method

In Fig. 9a, oxygen consumption ($\dot{V}_{O_2}$) is plotted separately for men on the two rations (full and reduced) during the second period of sled pulling and pack carrying on the icecap. (Values during the first period were not obtained because of need for modifying the mask.)

Rations $\dot{V}_{O_2}$ of the men on both rations decreased as the period progressed but dropped lower for the men on the reduced ration. Since body weights also decreased, this decrease in V_{O_2} should be expected. However, when plotted on a body-weight basis, there was still a statistically-significant decrease of V_{O_2} from beginning to end of the period (Fig. 9b), but the difference between those on different rations disappeared.

Load-carrying The effect of the load-carrying method on energy expenditure can be seen in Figure 10. Analysis of variance using all subjects shows a significant difference at the 1 percent level between the methods of load carrying. Greater energy expenditure is required when the load is carried on the back and sled than when it is totally on the sled.

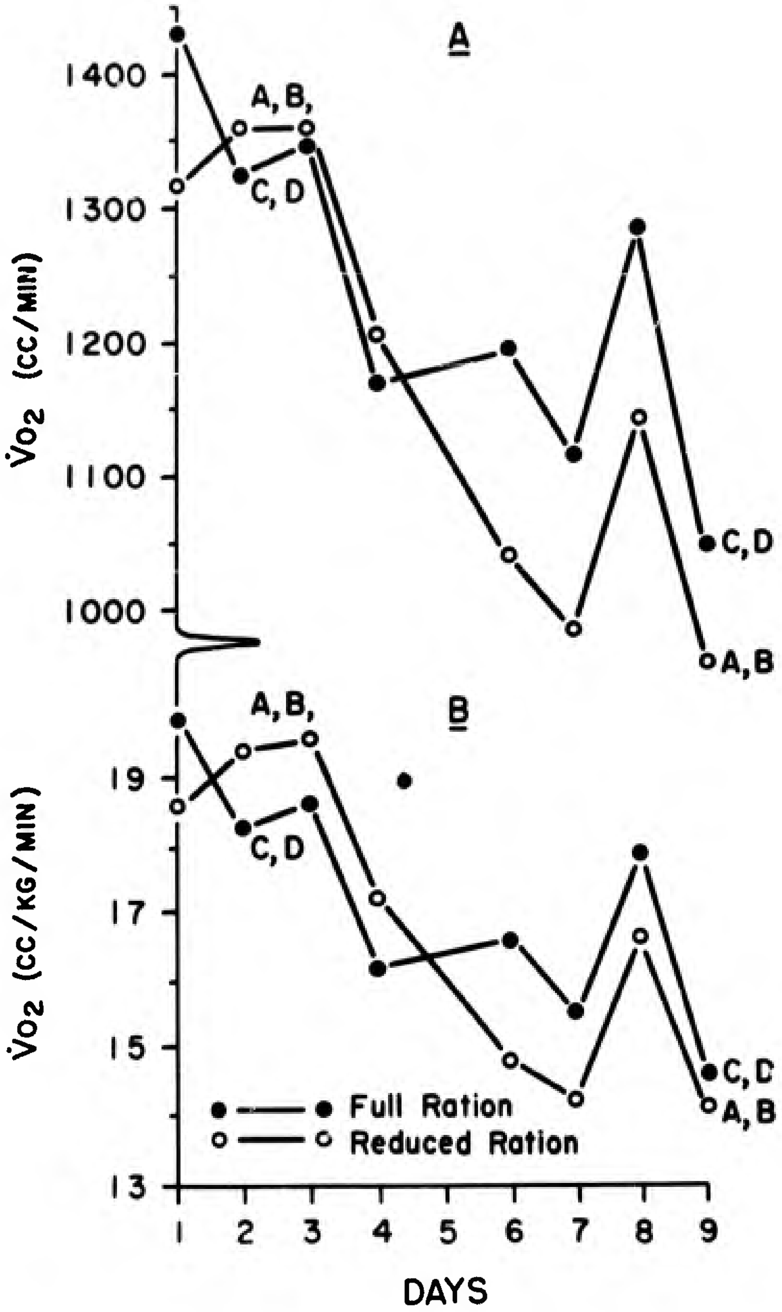

Figure 9 Oxygen consumption ($\mathring{V}_{O_2}$) during the daily trek in the second 10-day period. A. Total V_{O_2} in cc per minute. B. V_{O_2} per kilogram of body weight.

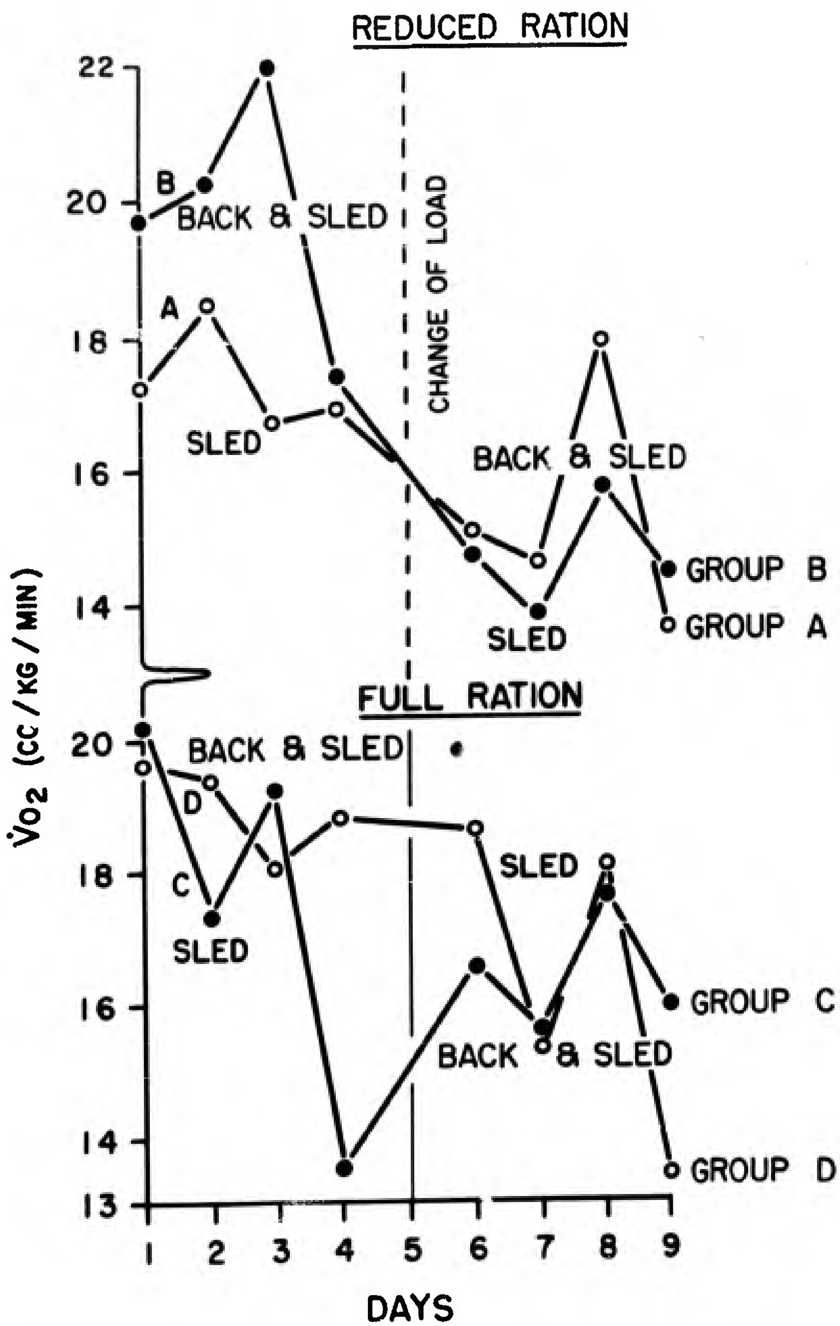

Figure 10 Comparison of oxygen cost of two load-carrying methods

This difference, however, is not as obvious for Groups C-and-D which were on the full ration.

Although the general trend of $\mathring{V}_{O_2}$ is downward, as the period of the trek continues, there is considerable individual variation (Fig. 12, appendix). For the 2 groups, B-and-C, there is, in general, an increase of $\mathring{V}_{O_2}$ on the 3rd day; groups A, C-and-D and some members of Group B show an increase on the 8th day. These changes cannot be correlated with any known experimental variables. There are day-to-day variations of $\mathring{V}_{O_2}$ which appear to be related to the time of day. About 62 percent of all afternoon values were higher than the corresponding morning values. Other diurnal fluctuations may have been hidden by the general downward trend and the special increases on the 3rd and 8th days.

e. Altitude factor (Mass of inspired air)

In Table VI it can be seen that the mass of air inspired while performing the altitude step test was not significantly different for the group 12 to 13 days after return from 7,000 feet to sea level. Since it was during this time at sea level that the relationship of V_I to $\mathring{V}_{O_2}$ was determined, it became unnecessary to develop an altitude factor to adjust for any difference in respiration. This fact was not known at the beginning of the study.

TABLE VI

MASS OF INSPIRED AIR AT 7,000 FEET AND NEAR SEA LEVEL (165 FEET)
(While performing altitude step test)

SUBJECT	AT 7,000 FT. (On icecap) Before 2nd trek		AT 7,000 FT. (On icecap) After 2nd trek		After return to 165 ft.	
	38th Day	39th Day	50th Day	51st Day	12th Day	19th Day
2	151.0	164.5	163.0	162.5	171.0	149.5
6	102.0	93.0	103.5	102.5	105.5	93.0
7	123.5	126.5	137.0	122.5	132.5	120.0
8	132.0	134.0	121.0	126.5	158.0	133.0
10	124.0	146.0	143.0	137.5	117.0	107.0
12	---	---	191.5	208.0	201.0	181.0
13	103.0	95.0	98.0	98.5	100.5	91.0
16	145.5	146.0	173.5	160.0	161.0	140.0
18	133.0	136.0	150.5	146.0	158.0	163.5

f. Inspired volume of air ($\mathring{V}_I$) on the icecap (7,000 ft.) and at Natick (165 ft.)

The mass of air inspired on the icecap was the same as that inspired at

Natick, up to at least 12 days after the return to Natick. Yet the actual volume of air inspired (i.e., air not adjusted to STPD conditions) was different, as would be expected. This was mostly because of the decrease of atmospheric pressure at the higher altitude. However, by the 19th day after return to Natick, the volume of inspired air had dropped lower so that the increase of inspired air on the icecap was 35 percent ± 28.2* of the sea level value (see Table VII). This is 8 percent ± 11.8* more than would be expected when the actual masses are compared (see Table VI). This is the same as adjusting the volume to STPD conditions.

TABLE VII

VOLUME OF INSPIRED AIR (BTPS) (liters/min) AT 7,000 FT. AND NEAR SEA LEVEL (165 FT.) (While performing altitude step test)

	At 7,000 Ft. (on icecap)		After return to 165 Ft.	
Subject	50th Day	51st Day	12th Day	19th Day
2	62.76	63.95	51.45	46.20
6	45.51	44.57	31.79	32.44
7	54.36	49.44	42.04	38.79
8	47.37	49.39	45.81	39.94
10	57.78	55.91	38.90	36.46
12	78.22	83.52	64.80	59.36
13	42.41	42.49	34.42	32.08
16	66.56	61.42	42.97	43.32
18	51.70	50.42	42.85	44.44

g. Respiratory volumes and physical fitness

As suggested earlier, the respiratory volume may be related to the level of physical fitness. Three sets of respiratory volumes were measured in this study:

1. Respiratory volumes during the altitude step test both at Natick and high on the icecap (9 men).

2. Respiratory volumes during the treadmill test used for determining individual curves of V_I vs $\dot{V}_{O_2}$ (19 men).

3. Respiratory volumes during the regular daily walk on the icecap (19 men). (These values, however, were not used in the physical fitness comparison because some men regularly did more work than others on the trail.)

* This value was determined from S.D. of the actual observations (not percent) and then converted to percent.

When rankings of the first 2 sets of respiratory volumes were compared with rankings of the scores of the HST for each man at the end of the second period, there was no significant correlation (Table XV and Table VIII).

TABLE VIII

RANKING OF SUBJECTS BY RESPIRATORY VOLUME DURING PERFORMANCE OF ALTITUDE STEP TEST AND BY SCORES ON THE HARVARD STEP AND TREADMILL TESTS

Subject No.	Respiratory Volume During Altitude Step Test		Scores on Harvard Step Test	Scores on Treadmill Fitness Test
	At Natick	On Icecap		
2	8	8	8	9
6	3	3	2	2
7	4	4	3	7
8	5	2	6	5
10	2	6	9	3
12	9	9	6	5
13	1	1	1	1
16	6	7	5	8
18	7	5	4	4

However, it was noted that of the 9 men taking the altitude step test, the 3 men who had the lowest respiratory volumes (lowest rank number) had scores of "excellent" (scores about 90) on the HST (i.e., an inverse relationship). Also, on the altitude step test, the respiratory volumes were not significantly correlated with the scores on the treadmill test. Because of considerable variation in respiratory volume among individuals, it might be expected that this relationship would apply more to a horizontal than to a vertical population study.

4. Discussion

a. Relation of food consumption to body weight

When caloric expenditure exceeds caloric intake, body weight decreases through the substitution of stored fat and body protein for the deficient calories. The decrease of body weight on 2400 calories in this study was therefore inevitable but was not expected on the "full" or 4800 calorie ration. The possible causes of this decrease when on the full ration are:

1. The new ration was less tasty, so less food was eaten.

2. Compensation for the sudden increase in the level of caloric expenditure may not be immediate when it is dependent on voluntary food consumption.

3. The water intake may have been inadequate. In the present study, water was less accessible than under most conditions, as is usual during work in cold climates, and water loss through sweating was high, so the water intake may have been inadequate. Unfortunately, difficulties with D_2O analysis prevented the determination of body water content.

After 4 to 5 days, caloric equilibrium was attained, as evidenced by body weight becoming stabilized. This was effected partly by an increase of voluntary food intake in the latter part of the period (Table XII, appendix) and also by a decrease in V_{O_2} during work on the trail (Fig. 9). It is significant that body weight curves (see Fig. 8) are similar in slope for the two groups on the full ration; this may attest to the similarity of the experimental conditions for both periods, as well as the genuineness of the body weight changes. However, this similarity of body weights among groups did not exist during the reduced ration periods and the reason for this remains obscure.

Frequently an attempt is made to determine the caloric equivalent of the weight loss. This can be done most accurately only when changes in body water, fat and lean body mass (protein) have been measured. The percent of weight loss due to changes in each of these factors seems to vary with, among other things, the length and severity of the caloric deficiency in the diet. This range goes from 25, 70 and 5 percent for fat, water, and protein, respectively, in the first 3 days on a diet reduced by one-third, to 85, 0 and 15 percent, respectively, for the 22nd to 24th days of the same diet (11). If the assumption is made that the first group of percentages given above most properly represents the proportion of components lost in the present study (since the total body weight losses were similar) then the actual level of caloric intake required (for our subjects) would be 3876 and 4464 Cal. for the two groups. This level compares favorably with the previous levels reported by us for men in an arctic-like situation (12). Others (13-17) who used accurate weighings of the food served and discarded, reported levels slightly lower than those of the present study; this may be reasonable to expect because of our high level of activity and above-average body weights. This level is above the level 3780 Cal/man/day suggested for heavy activity for an adult man in Canada and the United Kingdom and the 3430 Cal/man/day for "normal vigorous living in a temperate climate" (18).

b. Test evaluating physical fitness after reduced rations

Precisely-controlled laboratory studies (11) have shown that considerable caloric restriction could be tolerated for long periods without effecting a decrease in physical fitness scores as measured by running to exhaustion on the treadmill and by maximum oxygen uptake tests. Two series were run by this group. In the first series men consumed an all CHO diet of 530 cal/man/day, 19 percent of their actual caloric expenditure, for 12 days. Body weight decreased an average of 5.9 kg (about 13 lbs), which was 7.7 percent of the beginning body weight. In the second series, 1010 cal/man/day were consumed for 24 days. This intake was 33 percent of the actual caloric expenditure and body weight dropped 7.58 kg (about 17 lbs), which was 11 percent of the beginning body weight. The authors concluded from these and other studies that the level of body weight loss at which deterioration of ability to perform strenuous physical activity becomes noticeable is between 10 and 16 percent.

In other studies, Dyme (19), using USAF survival rations, found no deterioration in the HST scores during a 10-day period of moderate work on a caloric intake of either 45 or 17 percent of normal. However, the wide range of physical fitness changes in this study is hard to understand. Vaughan (20) reported considerable deterioration of fitness on a caloric intake of 25 percent of normal for 5 days, but this was believed to be due largely to the all-pemmican diet used.

These studies are excellent. However, one might wonder whether deterioration of physical fitness may set in at smaller caloric restrictions when: (1) the activity level is higher, and (2) during a field situation where multiple factors bear on the subject, including the important motivational factor. In the present study, physical activity was high and motivation was low; the low motivation was due to dislike for camping and regimentation, the inconveniences and restrictions of arctic living and the lack of variety in both the terrain and activity. Nevertheless, there was no deterioration of physical fitness during 10 days on a caloric intake reduced by about 40 percent of the voluntary intake. However, since only one level of caloric restriction was used in this study (2400 cal), the possibility still exists that these factors mentioned above may produce a deterioration of performance but only under more severe caloric restrictions.

Although the Harvard step test was used here as an index of physical fitness, it is not a fully adequate test. In fact, quantitative assessment of physical fitness is one of the most complex and controversial problems in applied physiology. This is due in part to the lack of general agreement on what constitutes fitness for withstanding various types of stress and in part from lack of agreement on what measurements allow valid comparisons to be made among individuals exposed to the same stress (21). In many cases, physical fitness refers to the capacity for prolonged heavy work. It is generally agreed that the fitness of the respiratory and circulatory systems are primarily involved. Since the heart rate is the easiest, most-meaningful heart function to measure, it has been used most frequently and is the basis of scoring in the Harvard step test. This test compares the rate of decrease of the heart rate after a standard exercise. However, considerable variation exists in the rate of decrease among individuals who are apparently at a similar level of fitness. As a result, the heart rate <u>during</u>, rather than following, exercise is being proposed as a better measure of fitness (2). This is the basis of the treadmill test used in the present study. Even this test does not completely eliminate the variability among individuals of apparently similar levels of fitness. It is considered, therefore, that these tests are better for comparing changes in the levels of fitness in the same individual rather than among individuals. One of the problems in measuring fitness is the absence of any absolute criteria short of exercising to exhaustion.

In view of the above, it was thought that assessments of fitness might be made by one's co-workers who were constantly present during the periods of hard work and rest; this would give an integrated picture of the levels of strength and fatigue that would more nearly approximate the absolute or real level of fitness. Even though one cannot be certain of the value of this subjective test, it was thought that a close correlation with a known test of fitness would confer a degree of validity to either test. Thus the lack of correlation of the subjective ratings to either exercise test (as shown in Table V) prevents any conclusion concerning any of these tests of fitness except that they are not measuring the same phenomenon. This difficulty emphasizes the inadequacy of the currently available tests of physical fitness.

c. Metabolism during work

Effect of ration Oxygen consumption was found to be lower on the reduced ration than on the full ration. This is probably due to a decrease in body weight, for, when oxygen consumption was calculated per body weight, no difference was found between these on the full or on the reduced ration. This means that the level of food reduction was not severe enough to produce the decrease of VO_2/kg body weight commonly associated with starvation.

Effect of load-carrying method The effect of the method of load-carrying on energy expenditure is equivocal. However, it would appear that it is more economical of energy, in general, for a man to pull a load on a sled than to carry it on his back when he is moving over a smooth and level snow surface.

Decrease in oxygen consumption: possible explanations The reason for the decrease in oxygen consumption per body weight on both diets from the beginning to the end of the trail period remains obscure. Possibly it results from a reduction of extraneous movements during exercise due to improvement in the skill of walking on snowshoes.

This possibility was also suggested under the "Results" section of this report to be the reason that the scores on the HST did not rise as much in the second as in the first period. However, it would seem that the previous 10-day experimental period, plus the training period of 4 to 5 days would have developed trail skills before the beginning of this period.

It does not seem probable that variations in the speed of movement on the trail would account for the decrease of $\dot{V}_{O_2}$ at the end of the 10-day trek. Even though this speed was not controlled precisely, the time of walking and the distance covered each day were roughly the same. A part of the decrease in oxygen consumption in groups B and D may be due to the change in the load-carrying method from back and sled to only sled in the middle of the period, but it does not account for the decrease in groups A and C as well.

One might wonder whether a progressive acclimatization to altitude might have altered the respiratory volume, thereby appearing to produce a decrease in $\dot{V}_{O_2}$. But again it might be expected that the previous 26 days at this altitude, including a similar 10-day trek, would have produced an acclimatization at an earlier date. This idea was supported by an examination of the data from the altitude step test taken before and after this second experimental period (Table VI). On this standardized exercise, there was not a decrease, but instead a small non-significant increase in respiratory volume during this period.

The reason for the oxygen consumption being higher in the morning than in the afternoon may be explained in part by the specific dynamic effect of the noon meal which closely preceded the afternoon activity and by the basic tendency of metabolism to rise as the day progresses (22).

There may be some question concerning the validity of the lowest values in Figure 12 in the appendix because the volumes of air inspired were close to the lower limit of accuracy suggested for this method (4). It was also surprising to observe a few values similar to those of men walking at 2 mph on a hard surface. One might not have expected levels of energy expenditure this low.

d. Altitude factor and respiratory volume at 7,000 ft.

Since there was little change in the mass of the respired gases from the values obtained on the icecap during the early days of return to Natick, at which time the ratios of $\dot{V}_I$ to $\dot{V}_{O_2}$ were determined, no adjustment for altitude, i.e., no altitude factor was necessary. However, between the time of the last measurements on the icecap and at Natick, mean body weight was increased by 3.29 kg. A weight increase would be expected to increase the respiratory cost of exercise. Therefore, the possibility exists that there was a slight decrease in respiratory volume due to the change in altitude which was hidden by the effect of increased body weights. But there is general agreement (23-26) that the respiratory volume which increases at a higher altitude remains high for a period after return to sea level. The length of time required for the reduction of respiratory volume to previous sea level values varies from one study to another, as do also the experimental conditions, but a period of as long as 2 weeks has been reported by Stickney (23) and Schilling (25). The physiological basis for the increase of respiration at a higher altitude and after return to sea level is discussed by Houston (26) and involves a decrease of the CO_2 buffer of the blood at the higher altitude with a slow return to normal at sea level. However, Pugh (10) in the study of one man returning from Mt. Everest found an almost immediate return of respiration to the control level upon return of the man to 10,000 feet from 25,000 feet and above. He feels that this may be due to a rapid adjustment learned by the body during frequent changes of a few thousand feet in altitude frequently required in moving from one camp to another in the exigency of supplying the advance camps and then escaping the strain of remaining at a very high altitude by returning to a camp at a lower level.

In the present study, by the 18th and 19th days at sea level, respiratory mass had decreased from the high level required on the icecap. If we assume the values found on the 18th and 19th days to be the true sea level values, we find that the difference in respiration between these values and those on the icecap cannot be explained completely by the adjustment of the volume to STPD but that an additional 6 percent is required at 7,000 feet. If the respiratory mass measured on the 18th and 19th days is not the final sea level value, then the increase would be even greater than 6 percent. The presence of this increase means, in effect, that respiratory volume is not independent of altitude. Schneider and Clark (27) had already reported this in 1926 and were followed by Houston and Riley (26) in 1947; the latter study used four subjects in an altitude chamber with progressively lower ambient pressures for 31 days. Rahn and Otis (8) also confirmed this principle. However, recently (1957) Pugh (10) stated that one climber who was studied both on Mt. Everest and before and after the ascent showed no effect of altitude on respiratory mass and Pugh concluded that this is the norm. Possibly part of this difference involves the use of both altitude-acclimatized and altitude-unacclimatized men.

5. Summary and Conclusion

In spite of the high level of exercise and low motivation, the ability to perform physical work as measured by the Harvard step test was not noticeably affected by a reduction of caloric intake of almost 40 percent below the voluntary intake and a resultant 4.5 percent decrease of body weight during 10 days of hard work. However, because of the limitations of the Harvard step test, it cannot be stated with absolute certainty that no deterioration in ability to perform physical work occurred. Results of other tests of fitness, the treadmill test and subjective evaluation by team co-members and investigators, did not validate the Harvard step test nor could they replace it. At the same time, subjective evidence of deterioration was apparent: a greater sense of fatigue, a lack of enthusiasm and an increased irritability.

Even though the energy cost of work on the icecap decreased from the beginning to the end of the 10-day work period on a body-weight basis, the reduction was not greater on the reduced ration than on the full ration. A load was pulled more easily when completely on a sled than when carried partly on the back, partly on the sled, in the type of snow surface present in this study.

The new method of determining energy expenditure used here was practical for field use but necessitated added laboratory work in order to find the relationship of oxygen consumption to the volume of inspired air for each individual. Because of the uncertainty of the respiratory effect of altitude on this relationship, a special altitude step test was performed in which it was learned that the volume of inspired air at the height of the icecap (almost 7,000 feet) was 8 percent above the sea-level volume even after adjustment to standard temperature and pressure. The volume of inspired air was 35 percent higher at 7,000 feet and remained higher for at least 12 days after return to sea level but had dropped to the lower level by 19 days at sea level. There was some evidence of an inverse relationship between the volume of inspired air and the scores on the Harvard step test.

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7. References

1. Brouha, L., N. W. Fradd and B. M. Savage. Studies in Physical Efficiency of College Students. Research Quarterly 15:211, 1944.

2. Åstrand, P. O. Human Physical Fitness with Special Reference to Sex and Age. Physiol Rev 36:307, 1956.

3. Boothby, W. M. A Determination of the Circulation Rate in Man at Rest and at Work. Am J Physiol 37:383, 1915.

4. Durnin, J. V. G. A. and R. G. Edwards. Pulmonary Ventilation as an Index of Energy Expenditure. Quart J. Exper Physiol 40:370, 1955.

5. Ford, A. B. and H. K. Hellerstein. Estimate of Energy Expenditure from Pulmonary Ventilation. J Appl Physiol 14:891, 1959.

6. Sartorelli, E. Med d Lavoro 47:350, 1956.

7. Botsch, F. W., J. J. Sacco and J. J. Powers. Personal communications.

8. Rahn, H. and A. B. Otis. Alveolar Air During Simulated Flights to High Altitudes. In Studies in Respiratory Physiology: Chemistry and Mechanics of Pulmonary Ventilation. Ed. by W. O. Fem, A. B. Otis and H. Rahn. Wright Air Development Center, AF Tech Rept No. 6528, Aug. 1951.

9. Schilling, J. A., R. B. Harvey, E. L. Becker, T. Velasquez, G. Wells and B. Balke. Work Performance at Altitude after Adaptation in Man and Dog. J Appl Physiol 8:381, 1956.

10. Pugh, L. G. C. E. Resting Ventilation and Alveolar Air on Mt. Everest; with Remarks on the Relation of Barometric Pressure to Altitude in Mountains. J Physiol 135:590, 1957.

11. Keys, A., H. L. Taylor and J. Brozek. Nutrition and Performance Capacity. QM Food and Container Institute, Chicago, Contract Research Project Report No. 13 (Final) Proj. No. 7-84-12-011, 1 June 1953 through 31 May 1958.

12. Buskirk, E. R., M. Kreider, R. Brebbia, N. Morana, F. Daniel, B. E. Welch, J. B. Mann, W. Insall, Jr., and T. E. Friedemann. Caloric Intake and Energy Expenditure In a Sub-Arctic Environment. QM Research and Development Command, Natick, Mass., Tech Rept EP-33, 1956.

13. Molnar, G. W., J. R. Blair, C. W. Gottschalk, W. M. Layton, L. E. Osgood, W. J. Zimmerman and C. A. Johnson. Energy Expenditure and Endurance of Men in an Arctic Bivouac. U.S. Army Med Dept Field Research Lab, Fort Knox, Kentucky, Rept No. 6-64-12-02-(13), April 1950.

14. Stadler, J. and M. I. Grossman. Food Intake of Soldiers Residing in the Sub-Arctic. U.S. Army Med Nut Lab, Denver, Colorado, Rept No. 161, 1955.

15. Welch, B. E., L. M. Levy, C. F. Consolazio, E. R. Buskirk, and T. E. Dee. Caloric Intake for Prolonged Hard Work in the Cold. U.S. Army Med Nutr Lab, Denver, Colorado, Rept 202, 1957.

16. Sargent, F. II, V. W. Sargent, E. Johnson and G. Stolpe. The Physiological Basis for Various Constituents in Survival Rations. Part II. The Efficiency of Young Men Under Conditions of Moderate Cold. Wright Air Development Center, Wright Patterson AF Base, Ohio, Tech Rept 53-484, Part II Vol. I., 1955.

17. Milan, F. and K. Rodahl. Nutrition and Energy Expenditure at Little America in the Antarctic. Arctic Aeromedical Lab, APO 731, Seattle, Washington, Tech Rept 60-11, 1961.

18. Albritton, E. C. Standard values in Nutrition and Metabolism, Wright Air Development Center, Wright Patterson AF Base, Ohio, Tech Rept 52-301, 1953.

19. Dyme, C. Arctic Field Trial of USAF Survival Rations. U.S.A.F. Air Materiel Command, Wright Patterson AF Base, Ohio, Tech Rept 6019, 1950.

20. Vaughan, D. A., H. F. Drury, J. P. Hannon, L. N. Vaughan and A. M. Larson. Arctic Survival Rations. VI. The Physiological Effects of Restricted Diets During Successive Winter Field Trials. Arctic Aeromed Lab, APO 731, Seattle, Washington, Tech Rept 58-8, 1959.

21. Johnson, R. E. Applied Physiology, Ann Rev Physiol 8:535, 1946.

22. Buskirk, E. R., P. F. Iampietro and B. E. Welch. Variations in Resting Metabolism with Change in Food, Exercise and Climate. Metabolism. 6:144, 1957.

23. Stickney, J. C. and E. J. Van Liere. Acclimatization to Low Oxygen Tension. Physiol Rev 33:13, 1953.

24. Hurtado, A. and H. Aste-Salazar. Arterial Blood Gases and Acid-Base Balance at Sea Level and at High Altitude. J Appl Physiol 1:304, 1948.

25. Schilling, J. A., R. B. Harvey, E. L. Becker, T. Velasquez, G. Wells, and B. Balke. Work Performance at Altitude after Adaptation in Man and Dog. J Appl Physiol 8:381, 1956.

26. Houston, C. S. and R. L. Riley. Respiratory and Circulatory Change During Acclimatization to High Altitude. Am J Physiol 149:565, 1947.

27. Schneider, E. C. and R. W. Clark. Studies on Muscular Exercise Under Low Barometric Pressure. Am J Physiol 75:298, 1926.

APPENDIX

SUPPLEMENTARY TABLES AND GRAPHS

TABLE IX

PHYSICAL CHARACTERISTICS OF THE 19 TEST SUBJECTS
AT THE BEGINNING OF THE STUDY

Subject (Name)	Height (Cm)	Weight (kg)	Age (Years)
1	167.6	63.00	20
2	167.6	68.92	18
3	175.3	66.36	19
4	167.6	65.07	22
5	177.8	80.26	20
6	177.8	62.24	20
7	182.9	75.47	23
8	170.2	68.56	18
9	177.8	86.39	23
10	182.9	72.14	23
11	180.3	77.46	23
12	182.9	86.08	20
13	182.9	63.54	20
14	170.2	64.47	20
15	172.7	81.36	23
16	180.3	69.27	23
17	182.9	83.23	20
18	185.4	64.34	24
19	182.9	65.34	18
Mean	177.3	71.76	21
Range	(167.6 - 185.4)	(62.24 - 86.39)	(18 - 24)

TABLE X

MEAN WEATHER CONDITIONS DURING EXPERIMENTAL PERIODS ON THE TRAIL

Day	Air Temperature (AM) (°F)	Air Temperature (PM) (°F)	Wind Velocity (AM) (mph)	Wind Velocity (PM) (mph)	General Wind Direction	Barometric Pressure (AM) (mm Hg)	Barometric Pressure (PM) (mm Hg)
				Period I			
1	-	24.2	7.3	10.0	NW	-	-
2	15.8	19.5	-	-	NW	594	594
3	17.5	20.3	12.3	8.4	N	594	595
4	12.8	17.5	9.3	8.2	W	601	602
5	16.0	20.8	14.3	14.6	WNW	602	604
6	20.8	26.0	9.7	12.2	WNW	606	605
7	22.8	24.0	12.7	8.8	WNW	605	604
8	24.8	27.8	-	-	W	603	601
9	19.2	22.7	12.0	10.0	NNW	598	597
10	21.2	27.5	-	-	WNW	599	600
Mean	19.0	23.0	11.1	10.3		600	600
				Period II			
1	14.5	22.7	6.3	5.8	WNW	-	-
2	18.8	23.8	7.0	-	WNW	594	596
3	17.5	19.8	2.0	0.2	W	598	599
4	14.8	21.8	8.7	7.0	WNW	599	599
5	20.0	24.8	14.0	-	NW	598	598
6	19.0	27.2	10.0	1.4	WNW	601	600
7	22.8	23.2	-	-	NNW	598	597
8	20.8	21.3	5.3	-	WNW	597	594
9	11.5	17.0	-	3.0	W	591	590
10	13.0	18.2	-	-	NNW	590	590
Mean	17.3	22.0	7.6	3.5		596	596

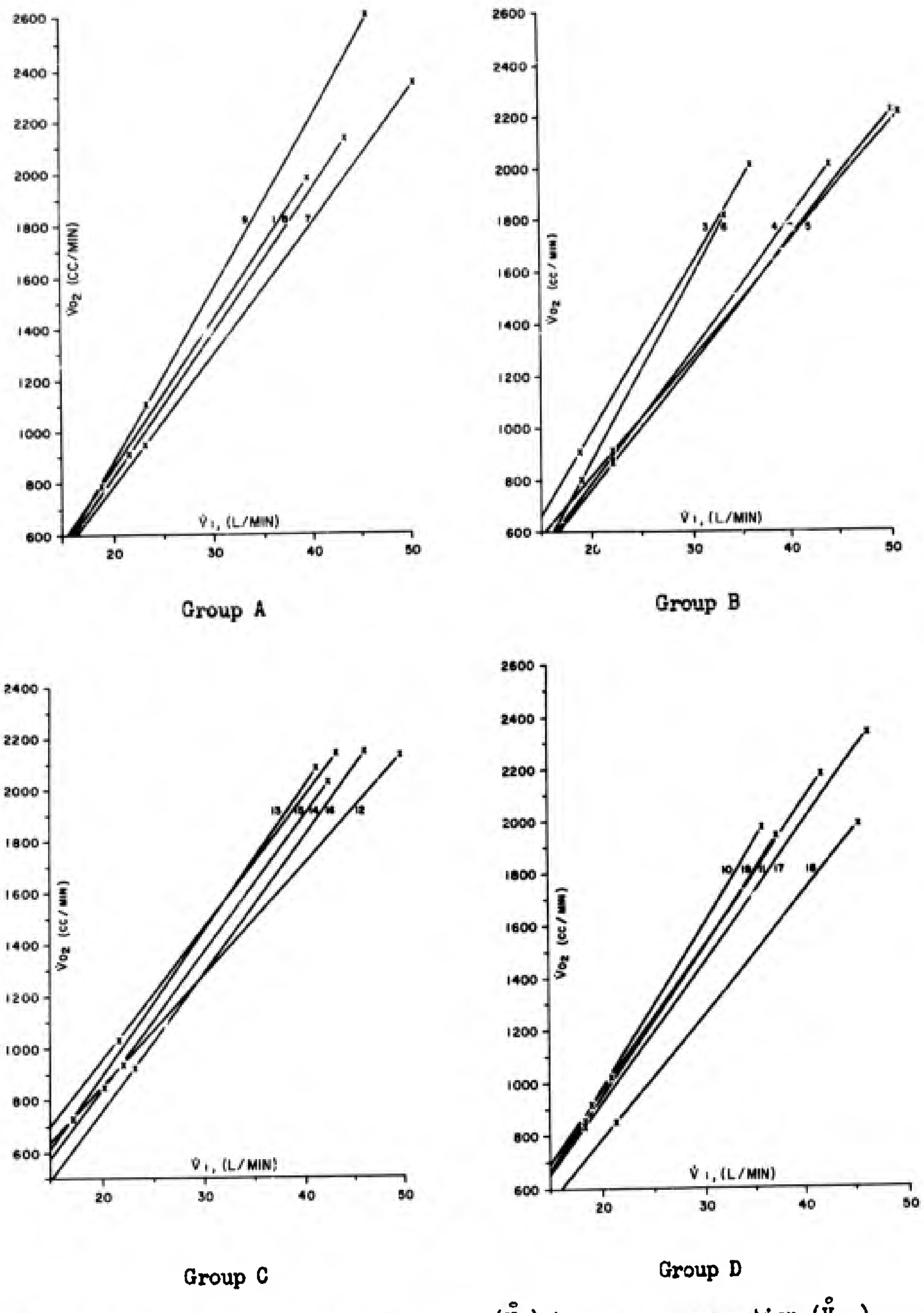


Figure 11 Ratio of respiratory volume ($\mathring{V}_I$) to oxygen consumption ($\mathring{V}_{O_2}$) determined for each man during two levels of exercise on the treadmill. The number on the curve identifies the subject.

TABLE XI

WEIGHT OF LOADS (Kg) CARRIED ON SLED OR ON BACK AND SLED

Group	Subject	Divided Load On Back	Divided Load On Sled*	Total Load on Sled
	1	13.76		
	7	14.59		
A	8	10.32	51.00	99.00
	9	14.44	61.70	95.00
	Mean	13.28	56.35	97.00
	2	15.24		
	3	13.83		
B	4	15.81	61.42	99.00
	5	14.15	58.13	95.00
	6	13.76		
	Mean	14.56	59.78	97.00
	10	13.90		
	11	17.37		
C	17	14.50	52.80	99.00
	18	15.55	60.60	95.00
	19	13.55		
	Mean	14.97	56.70	97.00
	12	15.74		
	13	14.49	56.16	99.00
D	14	15.85		
	15	17.53	50.63	95.00
	16	15.75		
	Mean	15.87		97.00

*Only two sleds to a team--they were pulled in turn by each man

TABLE XII

CALIBRATION FORMULA FOR CONVERTING MASK UNITS (MASS) INTO LITERS OF AIR PER MINUTE AT STP*

Mask of Subject	Formula (l/min)
1, 19	2.14 C +7.3
2, 15	2.32 C +6.1
3, 14	2.48 C +6.6
4, 16	2.26 C +6.6
5	2.40 C +5.0
6, 9	2.52 C +5.2
7, 11	2.40 C +5.6
8, 17	2.20 C +6.0
10, 13	2.42 C +6.3
12	2.50 C +7.4
18	2.02 C +6.2

*Ref (7)

TABLE XIII

FOOD CONSUMPTION
Period 1 25 July 1960 to 3 August 1960

Subject	DAY 1	2	3	4	5	6	7	8	9	10	Final
1	3357	3804	4045	3512	3336	4536	4784	4681	4408	4701	1843
2	3732	3226	2879	3084	3289	4439	4602	4294	3744	3908	2016
3	3299	2576	3367	3631	2780	3671	4436	4349	4536	3966	1787
4	3182	2943	3666	3371	3308	3531	3743	3848	3913	3715	1950
5	4109	3944	3881	2084	2989	4432	4276	3134	3882	3845	1564
6	3799	3639	3805	3305	3688	4027	4457	3952	2862	2662	1048
7	4163	3996	4459	3677	3756	4398	3570	3904	3568	4693	1684
8	2717	3153	3516	3840	2149	3082	2688	3055	3388	3479	1122
9	3411	2293	3075	2856	2751	2910	3476	3531	3531	3245	1320
10	1802	2194	2320	2343	2386	2348	2423	2315	2289	2383	1159
11	2237	2408	2459	2295	2466	2356	2423	2361	2413	2453	1110
12	1711	2408	2322	2392	2415	2348	2423	2304	2413	2449	1159
13	1729	2146	2336	2392	2379	2263	2423	2361	2413	2453	1159
14	1727	2359	2452	2392	2466	2328	2423	2361	2413	2453	1155
15	2209	2408	2459	2295	2466	2356	2423	2361	2413	2453	1159
16	2295	2408	2458	2225	2010	2356	2423	2361	2413	2336	1159
17	2267	2408	2316	2131	2186	2253	2253	2223	2363	2305	1159
18	2262	2408	2458	2392	2466	2356	2423	2361	2413	2453	1159
19	2120	2354	2458	1692	2420	2356	2233	2335	2413	2453	1159

TABLE XIII (Continued)

FOOD CONSUMPTION
Period 2 — 12 August 1960 to 21 August 1960

Subject		DAY 1	2	3	4	5	6	7	8	9	10	Final
1	3961	2362	2312	2326	2507	2467	2448	2366	2337	2377	2558	1252
7	3073	2358	2263	2326	2507	2467	2293	2366	2329	2377	2529	1252
8	4142	2246	2312	2198	2507	2302	2299	2265	2270	2373	2318	1232
9	3398	2033	2312	2284	2435	1861	2318	2202	2311	2337	2482	1231
12	3544	2366	2312	2330	2507	2467	2348	2366	2337	2373	2558	1256
11	4445	2299	2312	2313	2507	2467	2348	2358	2333	2381	2543	1256
4	3958	2366	2305	2330	2507	2373	2311	2358	2329	2373	2555	1252
6	3492	2366	2259	2131	2430	2421	2340	2366	2301	2296	2559	1252
5	3602	2366	2291	2330	2191	2446	2348	2341	2337	2381	2563	1256
13	4028	2953	4293	4446	4154	4447	4262	4470	4208	4338	3546	2448
14	3218	3794	402	3616	3866	4050	3762	3877	3811	4244	3500	2477
19	3799	3256	3947	3826	3659	3896	4019	3841	3854	4136	3722	2477
20	4291	4167	4253	3906	3911	4903	4019	4177	4054	4165	3818	2329
21	4053	3929	4127	3574	4015	4266	3712	3686	3971	3731	3779	2211
24	3143	4215	4343	4741	4737	4845	4780	4618	4688	4822	4919	2477
23	3785	4006	3180	3735	3549	3908	4454	3642	3845	3992	4206	2391
16	3616	4293	3460	3563	4111	4796	4362	4381	4153	4321	4367	2477
17	4540	4547	4190	4669	4828	490[illegible]	4690	4618	4642	4641	4509	2342
18	3022	3933	4234	3913	3736	4134	4709	4543	4385	4719	4115	2427

TABLE XIV

INDIVIDUAL HARVARD STEP TEST SCORES BEFORE AND AFTER EACH EXPERIMENTAL PERIOD

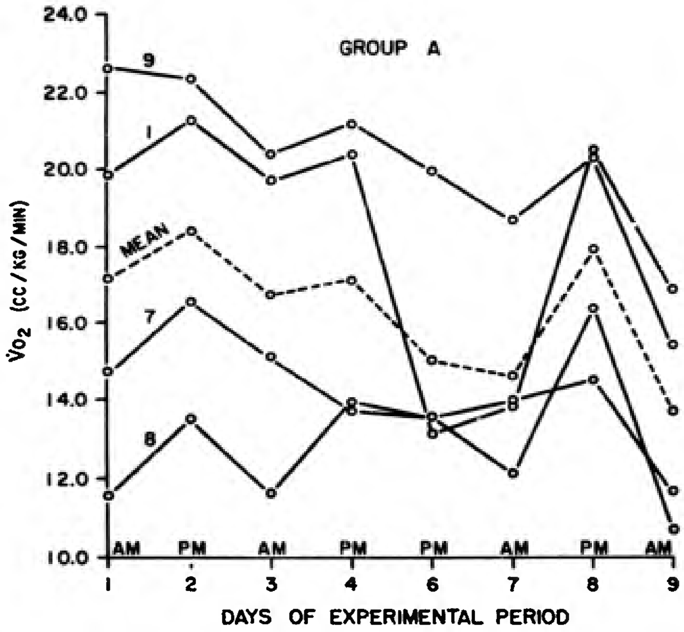
	1st 10-Day Experimental Period							2nd 10-Day Experimental Period					
	Before Period				After Period			Before Period			After Period		
Subj.	Trial 1	Trial 2	Trial 3	$\bar{x}$	Trial 1	Trial 2	$\bar{x}$	Trial 1	Trial 2	$\bar{x}$	Trial 1	Trial 2	$\bar{x}$
	Full Ration							Reducel Ration					
1	81	89	76	82	110	93	102	86	82	84	92	99	95
2		68	73	70	73	73	73	72	83	77	74	85	78
3	79	74	75	76	96	90	93	80	84	82	98	91	94
4	92	90	85	89	110	103	106	90	91	91	96	95	95
5	81	78	82	80	91	88	90	85	91	88	92	89	95
6	109	--	106	107	123	118	120	97	107	102	111	--	111
7	78	85	87	83	107	106	106	90	86	88	92	95	93
8	77	75	70	74	89	77	83	75	78	77	85	85	85
9	81	79	--	80	89	87	88	87	80	84	88	89	88
	Reduced Ration							Full Fation					
10	72	67	68	69	81	86	84	85	80	83	75	79	77
11	70	60	64	65	76	76	76	70	77	74	77	--	77
12	71	75	81	76	88	96	92	82	79	81	82	89	85
13	103	103	107	104	139	119	129	109	107	108	109	123	116
14	76	77	80	78	81	91	86	75	79	77	83	--	83
15	84	82	80	82	102	109	106	89	85	87	92	--	92
16	82	83	82	82	90	91	90	88	84	86	86	--	86
17	--	72	72	72	73	82	78	78	80	79	67	--	67
18	73	75	75	74	84	89	86	82	82	82	82	92	87
19	--	81	83	82	101	88	94	87	82	85	100	--	100

Full Ration = 4800 Cal
Reduced Ration = 2400 Cal

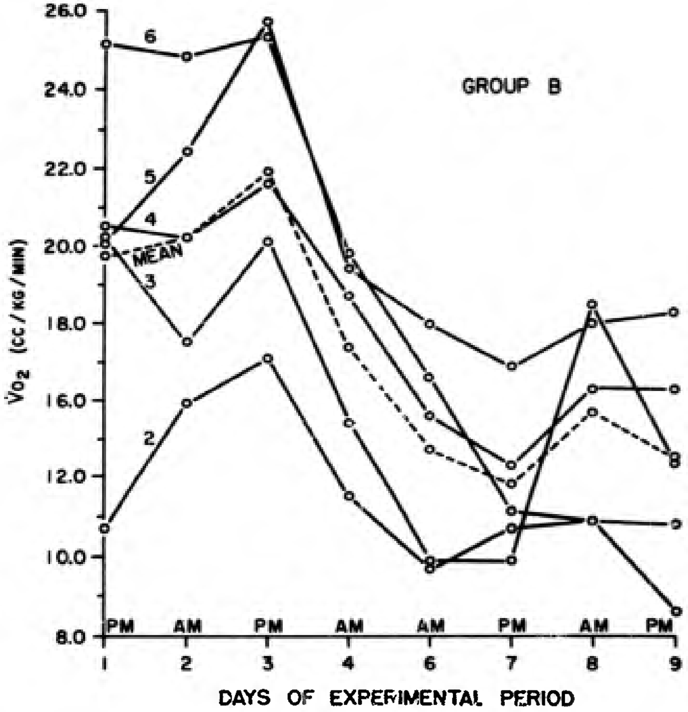
TABLE XV

RANKING OF SUBJECTS BY TESTS AND SUBJECTIVE ESTIMATES OF PHYSICAL FITNESS AND BY ESTIMATES OF ABILITY TO PERFORM ALONE ON THE ICECAP

Team	Subject No.	Fitness Tests: HST	Fitness Tests: Treadmill	Respiratory Volume per Body Weight Walking on Treadmill	Subjective Estimates of Fitness: By Invest.	Subjective Estimates of Fitness: By Subject	Performance Alone: By Subject
A & B	1	2	5	11	2	1	1
	2	9	8	16	8	5	5
	3	5	3	6	7	7	9
	4	2	2	19	5	4	7
	5	2	7	10	4	8	5
	6	1	1	12	1	1	2
	7	6	5	17	3	3	3
	8	8	3	13	9	8	8
	9	7	9	6	6	6	4
C & D	10	8	2	3	9	3	5
	11	8	5	9	2	1	3
	12	6	4	3	7	6	6
	13	1	1	2	3	7	1
	14	7	6	14	8	7	7
	15	3	8	5	4	10	7
	16	5	6	18	5	5	10
	17	10	10	1	10	9	9
	18	4	3	15	1	2	4
	19	2	8	6	5	4	2



Group A



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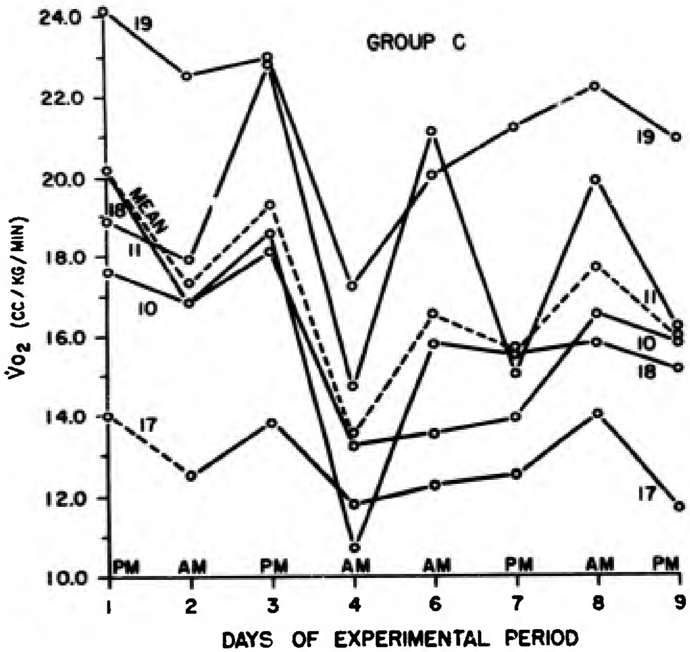
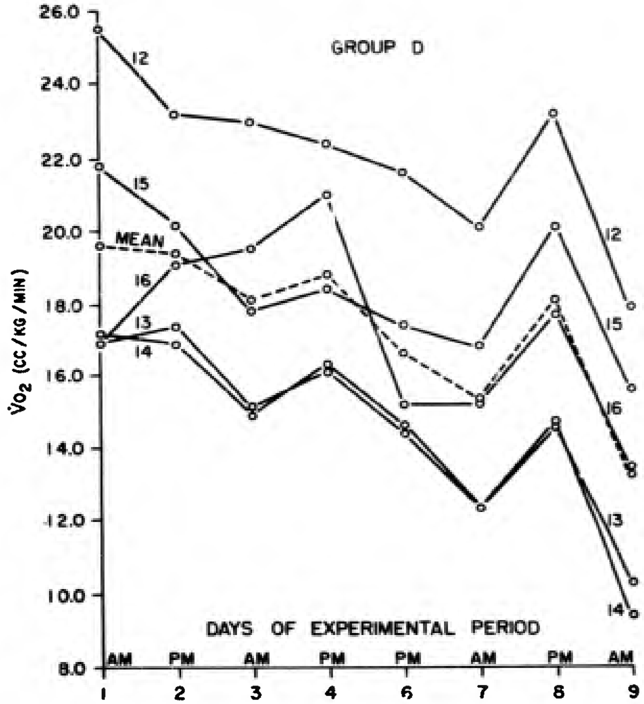


Group C



Group D

Figure 12 Oxygen consumption ($\mathring{V}_{O_2}$) for each man during the daily trek in the second 10-day period

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Quartermaster Research & Engineering Center, Natick, Mass. EFFECT OF REDUCED RATION AND METHOD OF LOAD CARRYING ON PHYSICAL FITNESS AND ENERGY EXPENDITURE OF SMALL GROUPS OF MEN OPERATING ON THE GREENLAND ICECAP by Marlin B. Kreider, Thomas Dee and John A. Vaughan. July 1961, 50 pp illus (Technical Report EP-160).

Early in the summer of 1960 a group of 19 young soldiers were transported from Fort Lee, Virginia, to the Greenland icecap where they were studied during 2 treks of 10 days each over the icecap. A period of training and acclimatization preceded the studies and some measurements were made both before and after each trek. Finally, some measurements were also made at sea level after return to Natick, Mass.

The subjects hiked 8 miles each day, divided into 2 major groups: one living on a full ration, and the other on a ration reduced by about 40% of the voluntary caloric intake. Both groups were further subdivided according to either of two methods of load carrying: (1) on the back and sled, (2) entirely on the sled. The method was alternated for each man during the second half of the 10-day period; also the alternate ration regimen was used during the second period. The following measurements were made:

(1) Physical fitness was measured by performance on the Harvard step test before and after each experimental period. After return to sea level, performance on this test was also compared with performance on the treadmill. In addition, the subjects ranked each other by their subjective estimate of fitness.

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1. Adaptation (Physiology)
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